CGILS: A Project to Understand Climate Feedbacks of Low Clouds in GCMs

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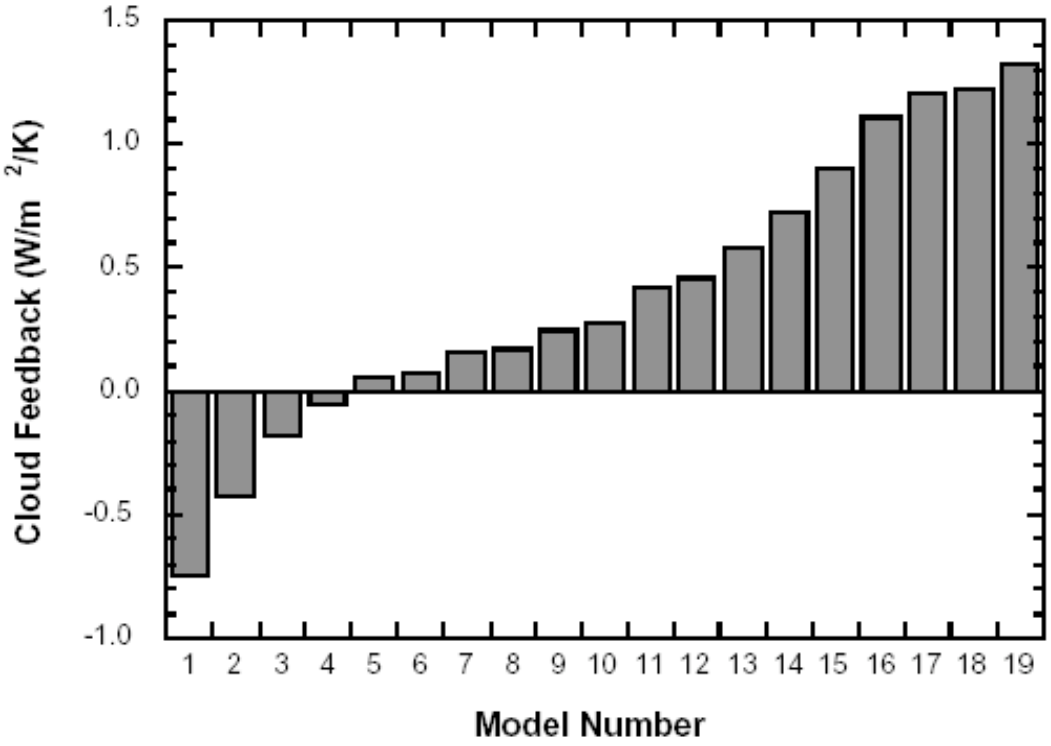
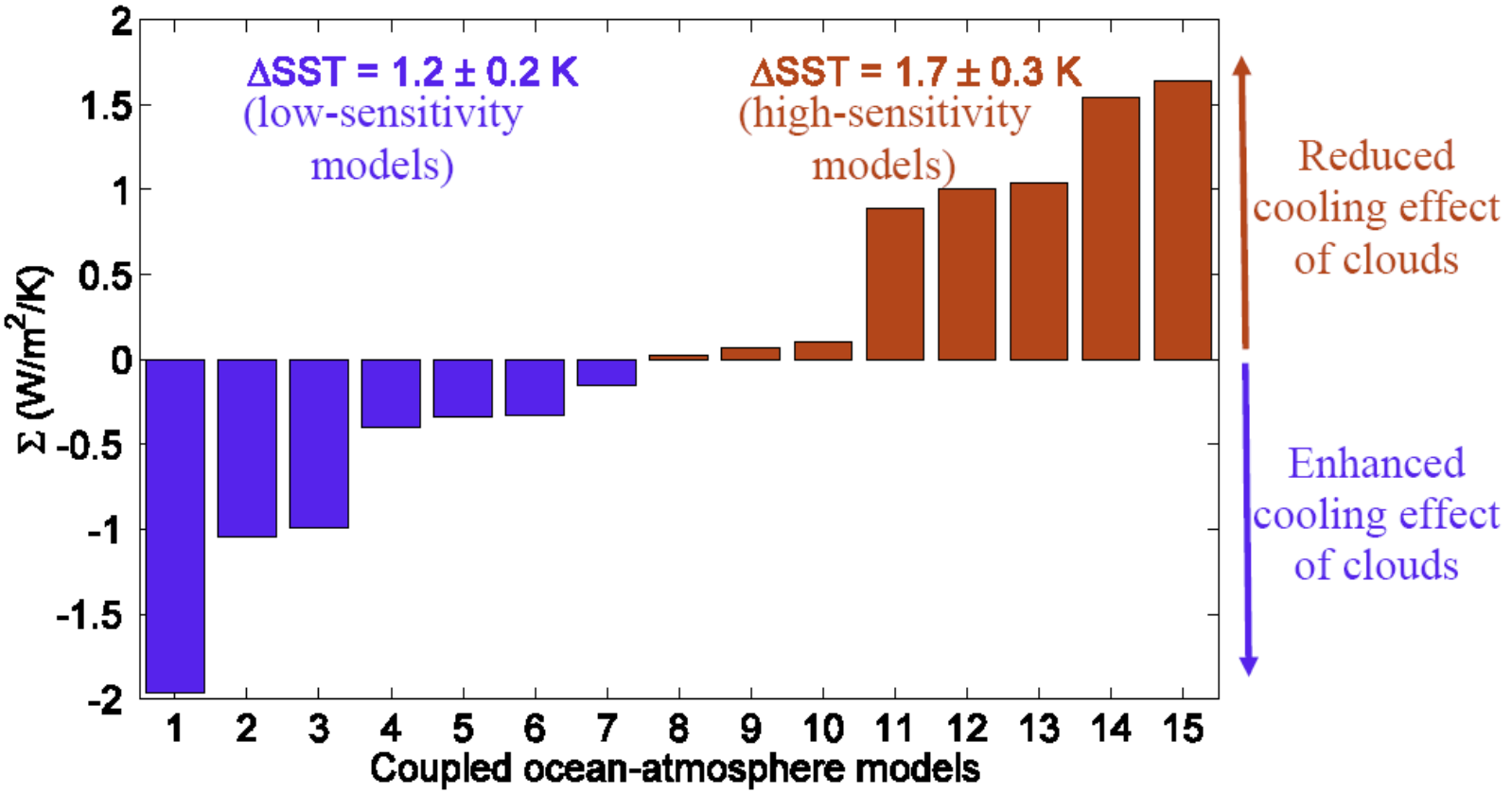
Stony Brook University, State University of New York
And CGILS Participants

CERES Science Team Meeting, April 27-29, 2010



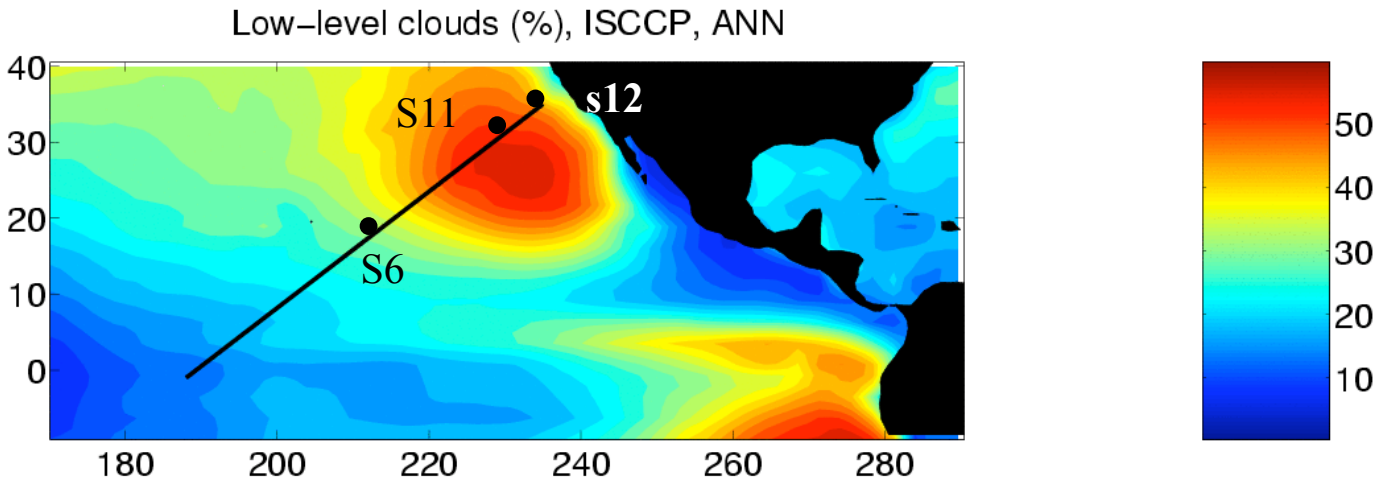
(Cess et al. 1990)

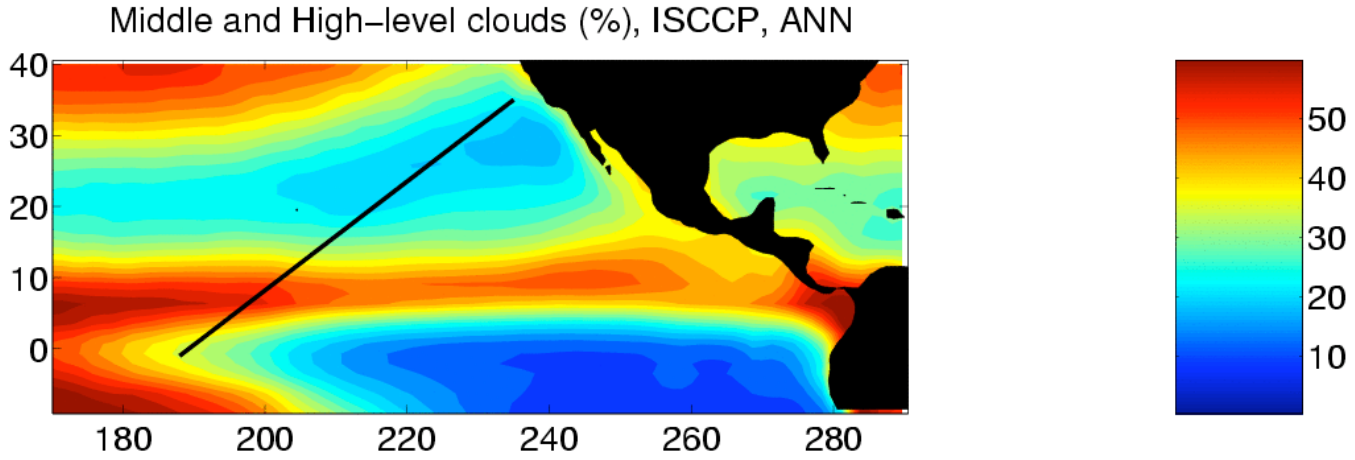
Sensitivity of the Tropical NET Cloud Radiative Forcing (CRF)
to surface temperature change ($W/m^2/K$)



(Bony and Dufresne, GRL, 2005)

GPCI

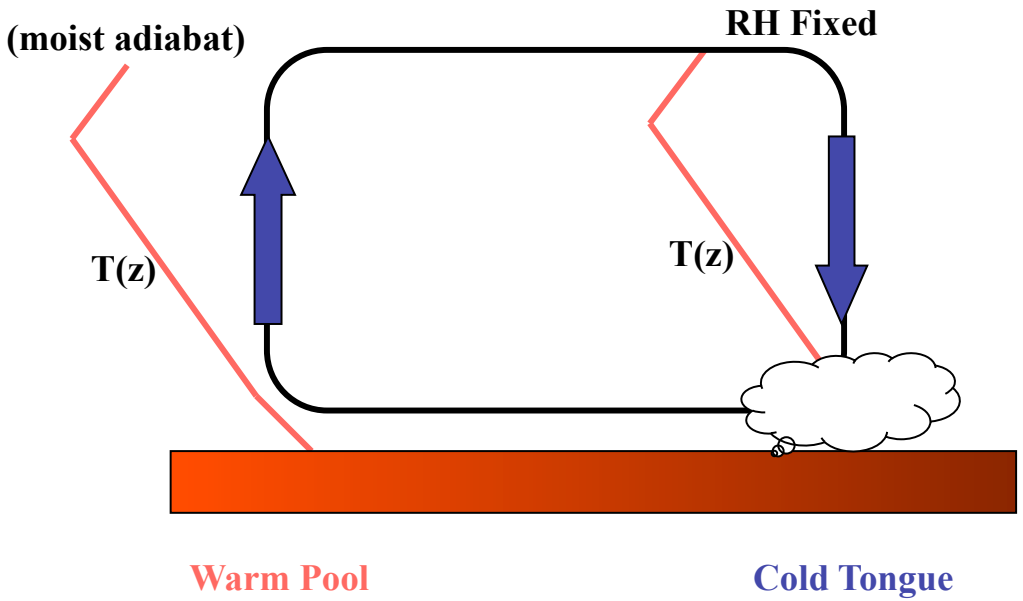

Low–level clouds (%), ISCCP, ANN
S11
s12
S6
40
30
20
10
0
180
200
220
240
260
280
50
40
30
20
10


Middle and High–level clouds (%), ISCCP, ANN
40
30
20
10
0
180
200
220
240
260
280
50
40
30
20
10

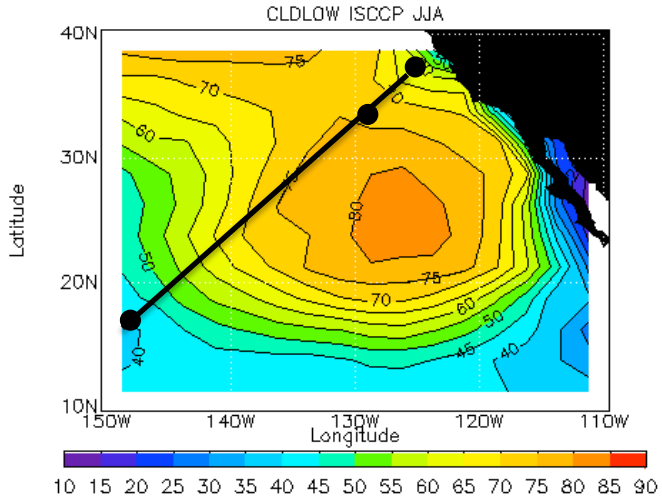
The Idea:

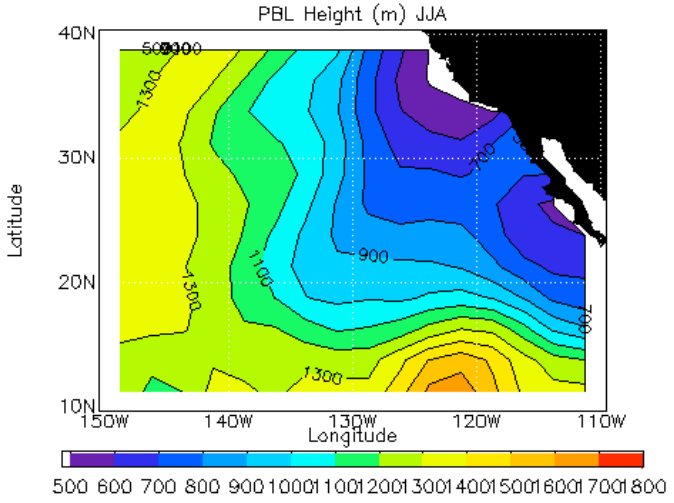
- Simplify the problem by isolating physics from dynamics
- Use idealized dynamics - GCM independent, interactive with SST, can do climate change experiments

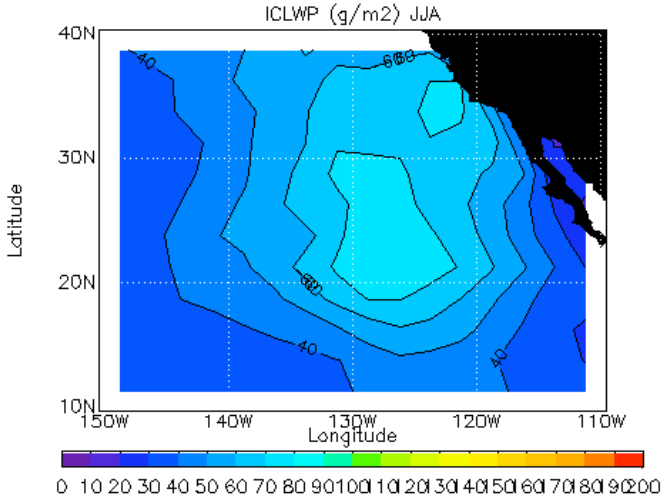
Relevant to GCM clouds and observations

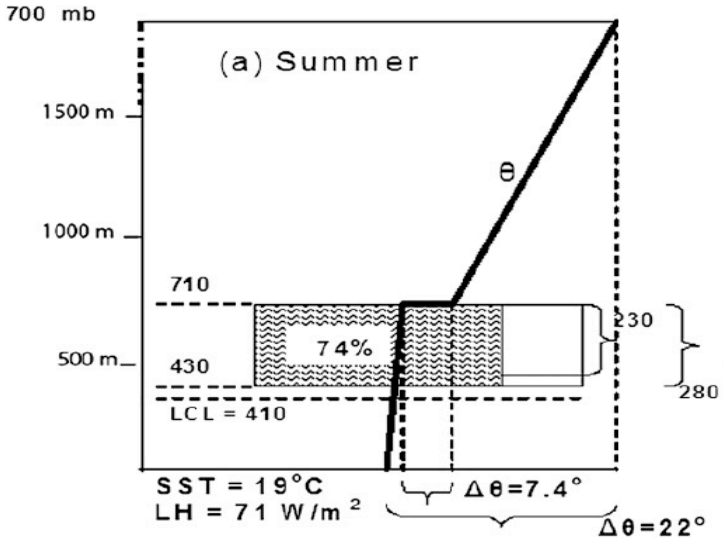


Synthesis of Observations





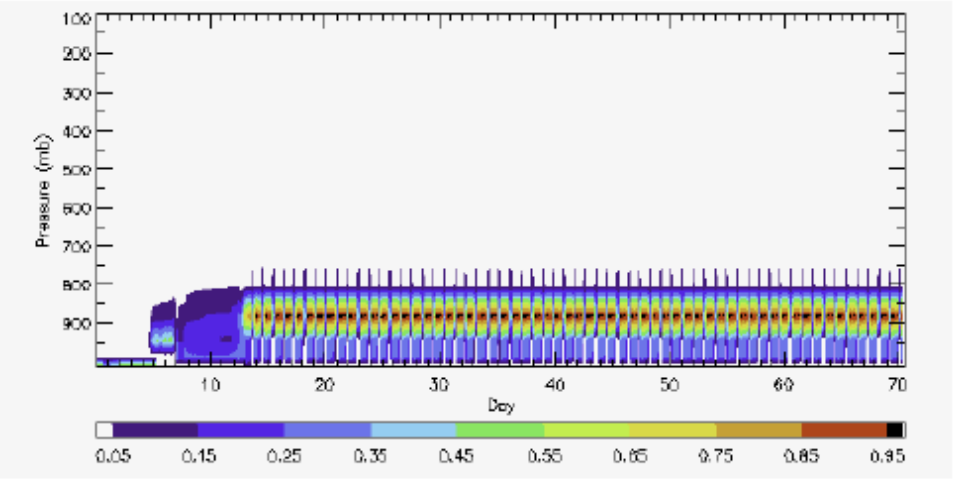


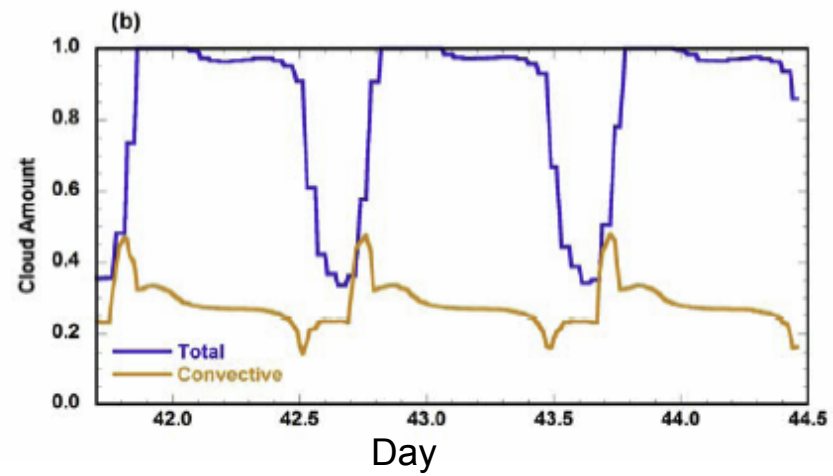


(Lin, Zhang and Loeb, JCL 2009)

Clouds in CAM3

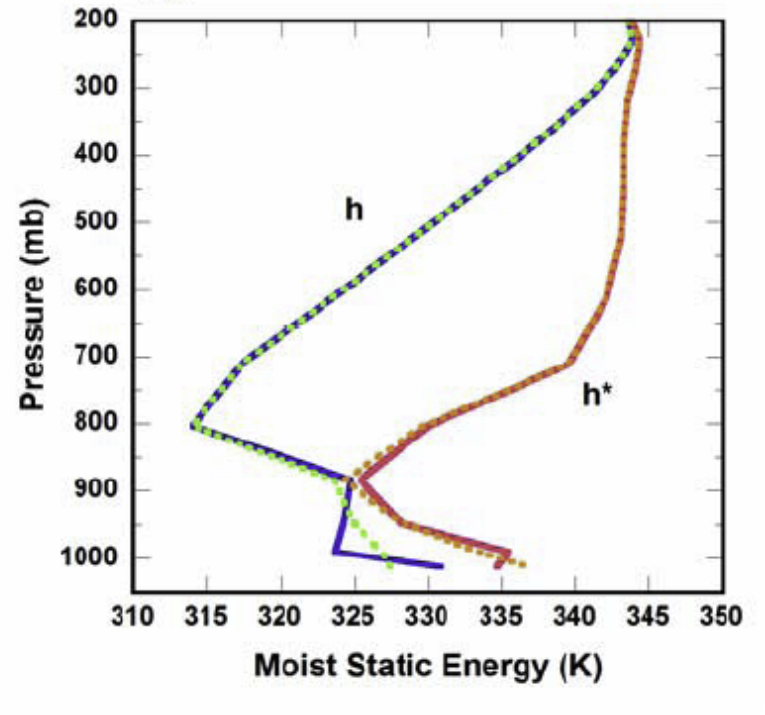
A Time Segment

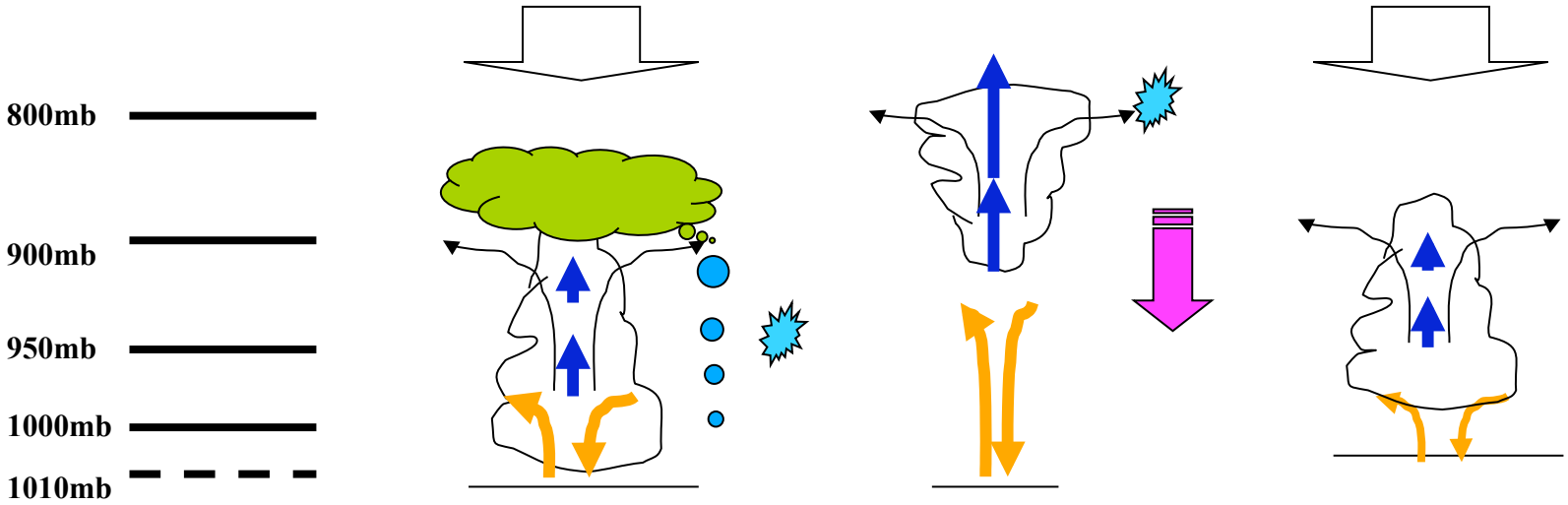




Total and Convective Cloud Amount

The penetrative convection and shallow convection

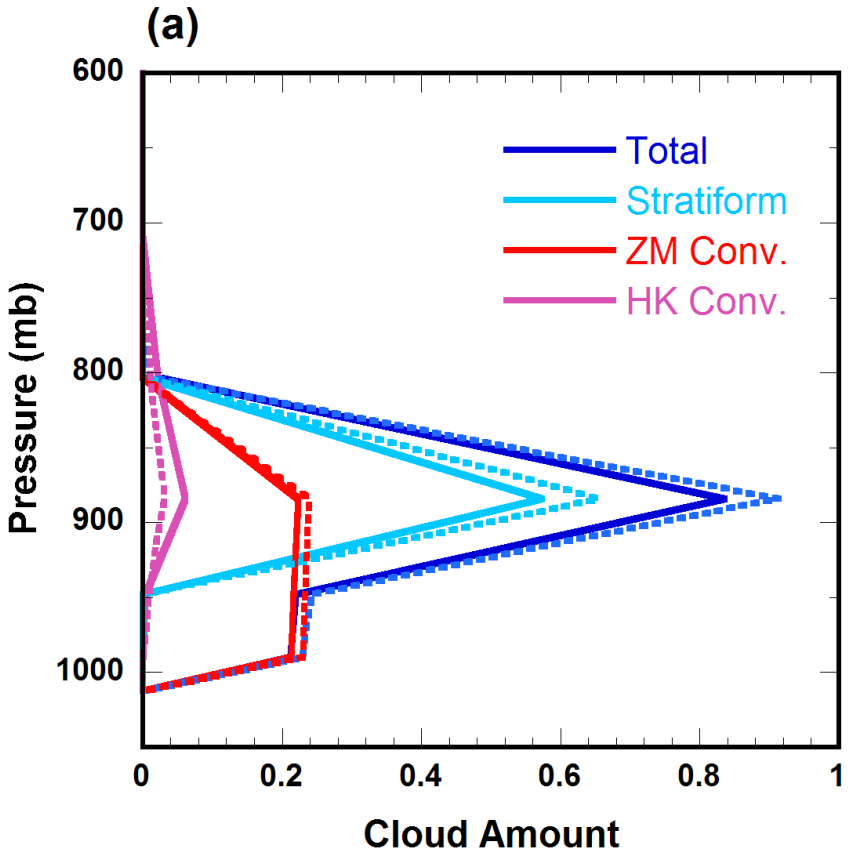




Interaction of Parameterizations!

(Zhang and Bretherton 2008)

Cloud Feedback: Change of Cloud Amount (Solid to Dashed)



Convective mass flux increased. $h_0 - h_z^* = (s_0 - s_z) + L(q_0 - q_z^*)$

1. **Are they correct?**

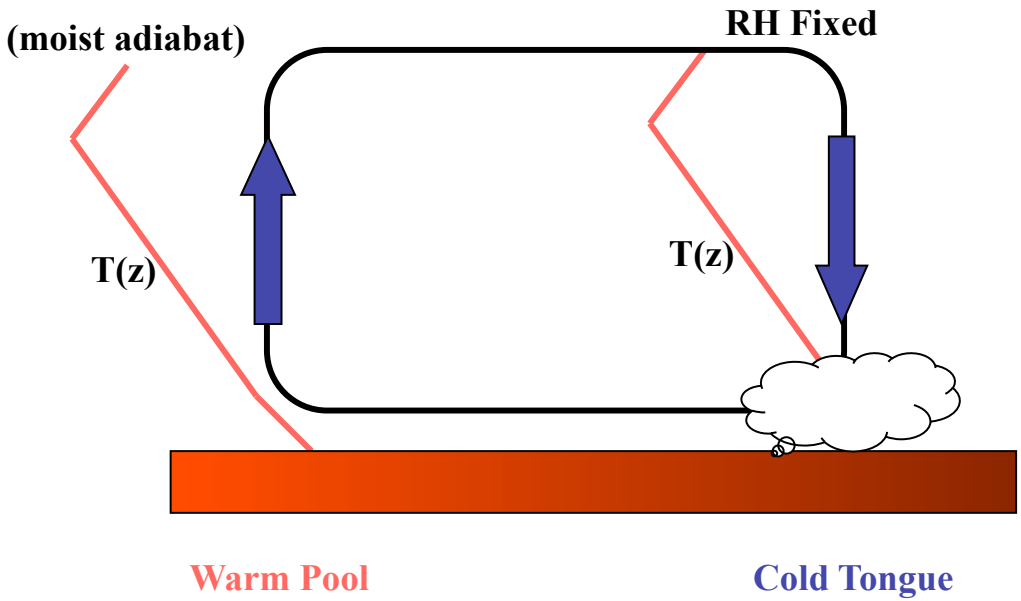
2. **What are the mechanisms in other models?**

CGILS

CFMIP-GCSS Intercomparison of Large-Eddy and Single-Column Models

CFMIP: Cloud Feedback Model Intercomparison Project

GCSS: GEWEX Cloud System Study



(Zhang and Bretherton, 2008)

The objectives:

1. To understand the models and their cloud feedbacks

2. To compare with LES/CRM simulations

3. To compare with observations

SCM (16)

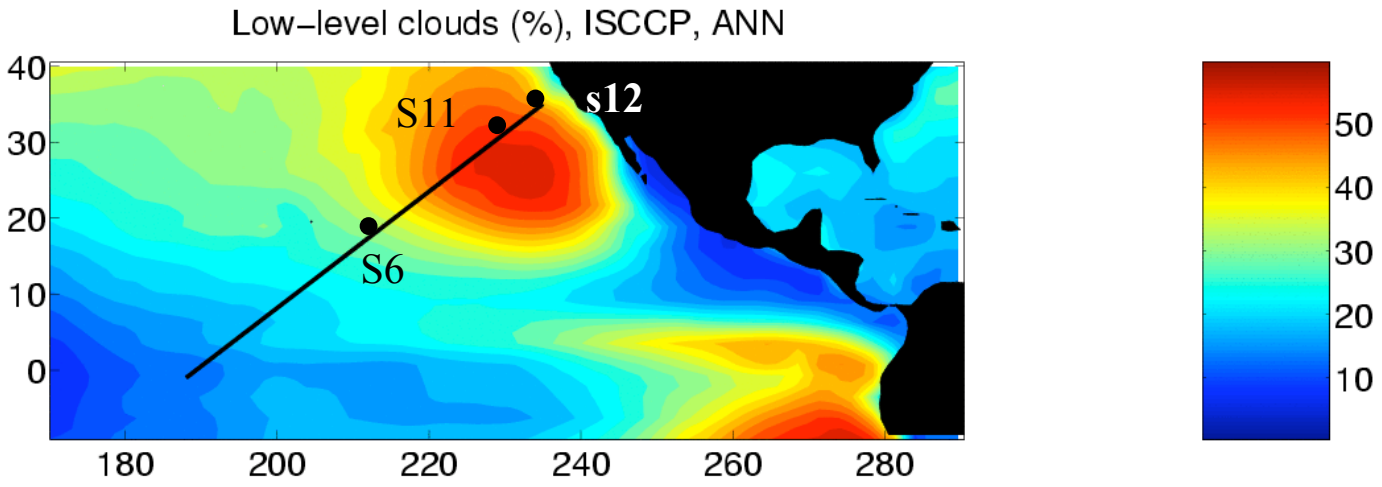
CAM3
CAM4
CCC
CSIRO
ECHAM5
ECHAM6
ECMWF
GFDL
GISS
GSFC
JMA
KNMI
LMD
SNU
UKMO
UWM

LES (5)

UCLA/LaRC
SAM
KNMI
UCLA/MPI
UKMO

Results submitted to date

GPCI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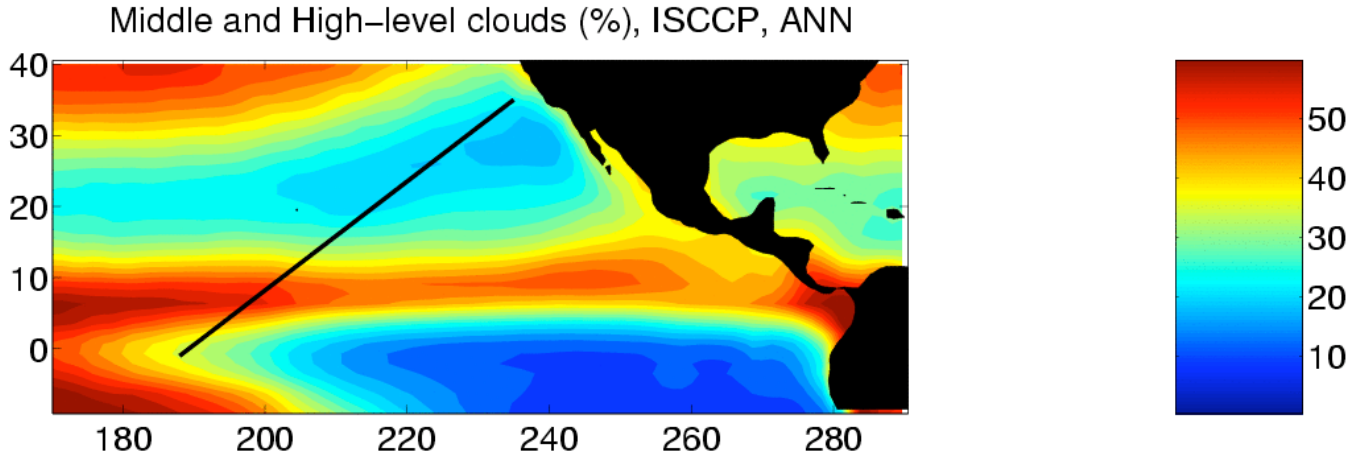
Middle and High–level clouds (%), ISCCP, ANN
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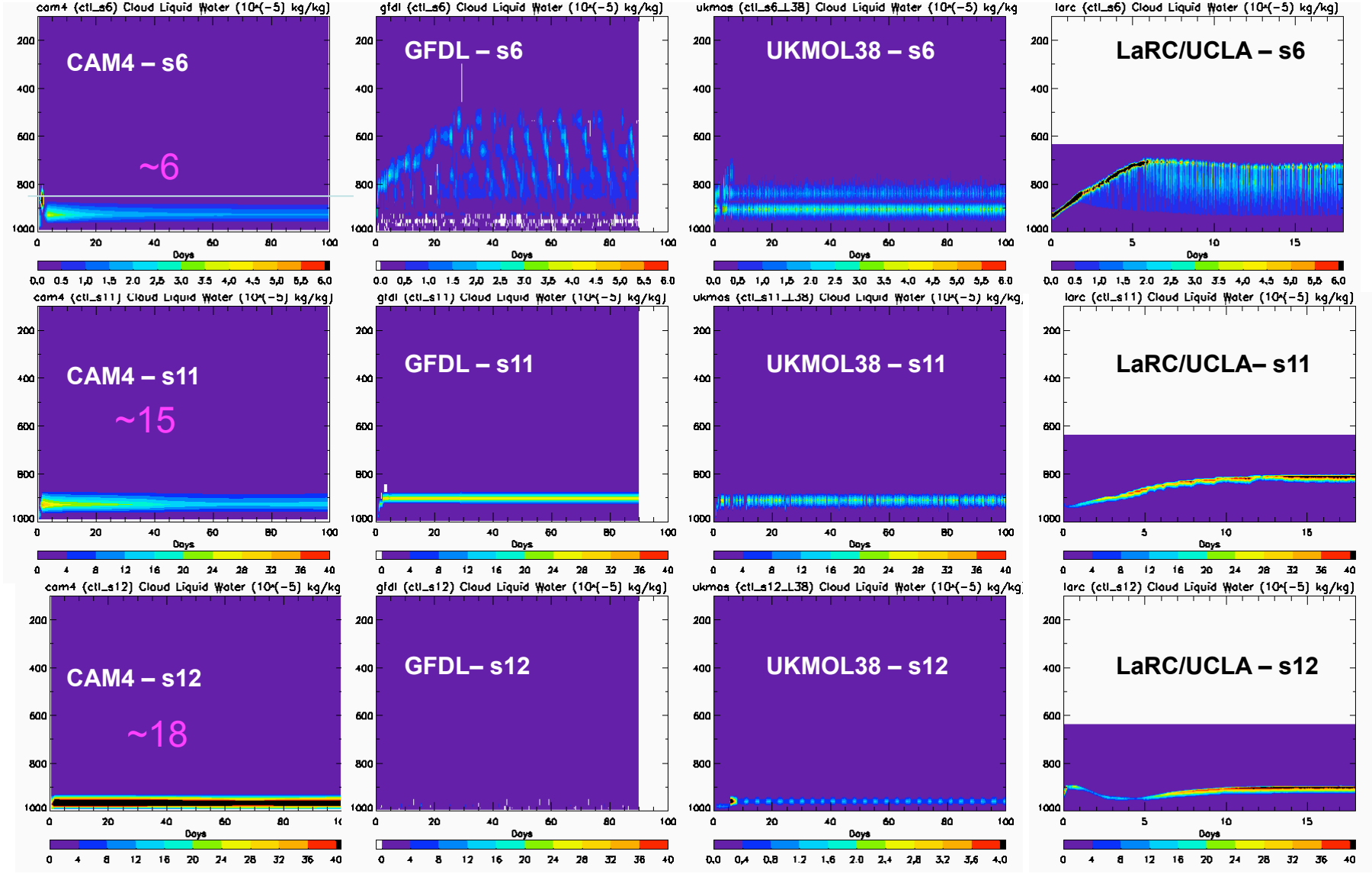
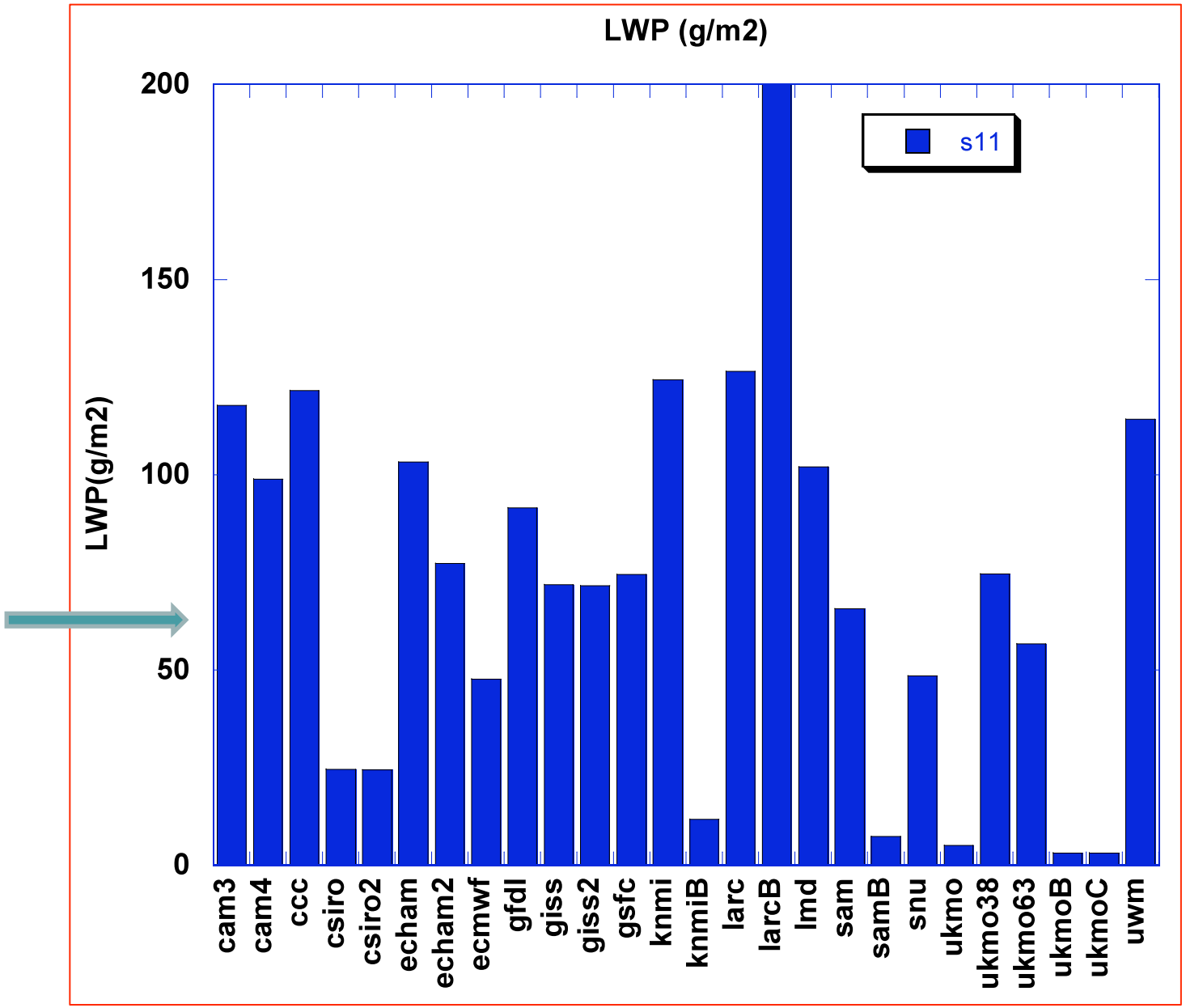
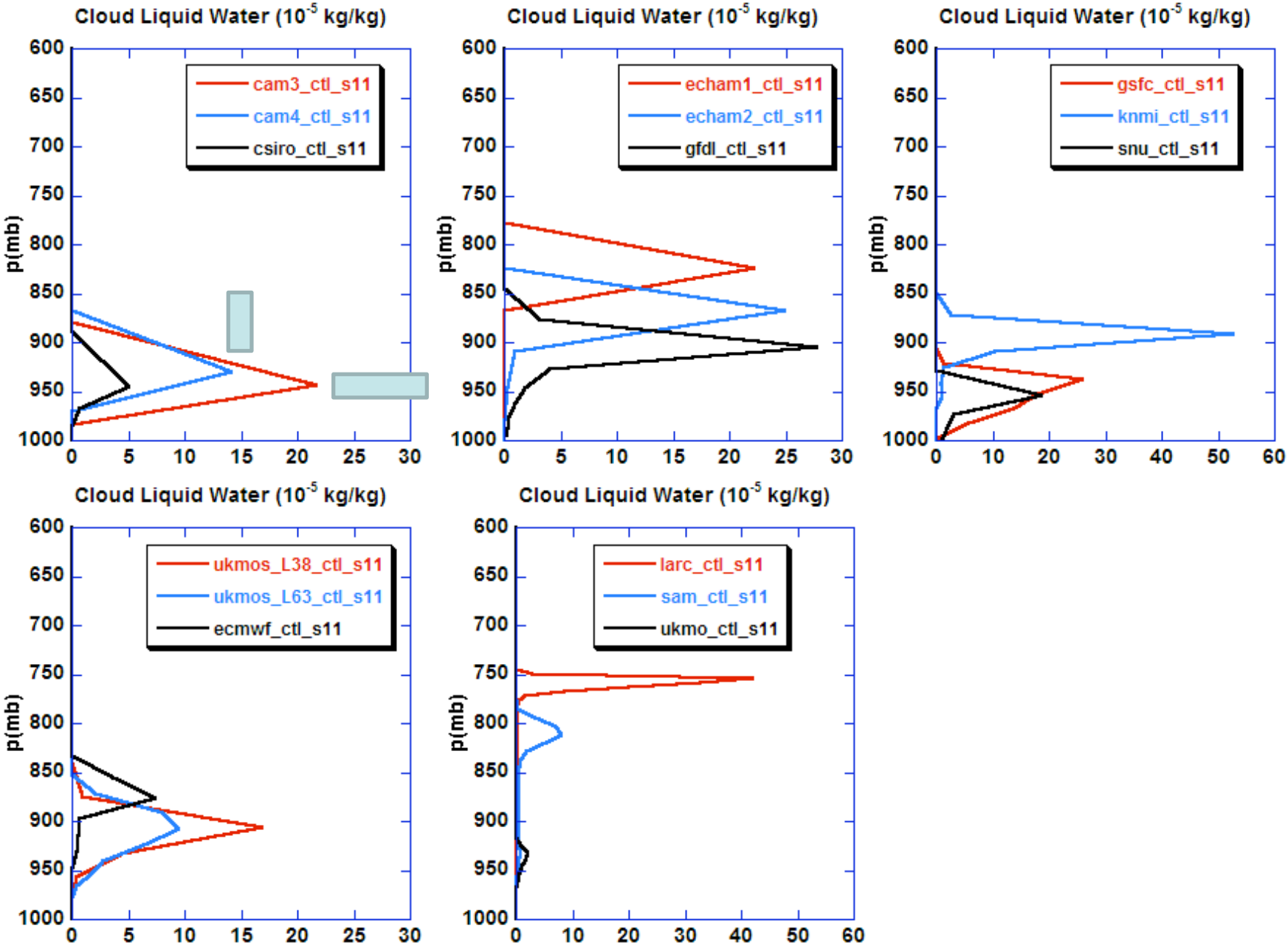
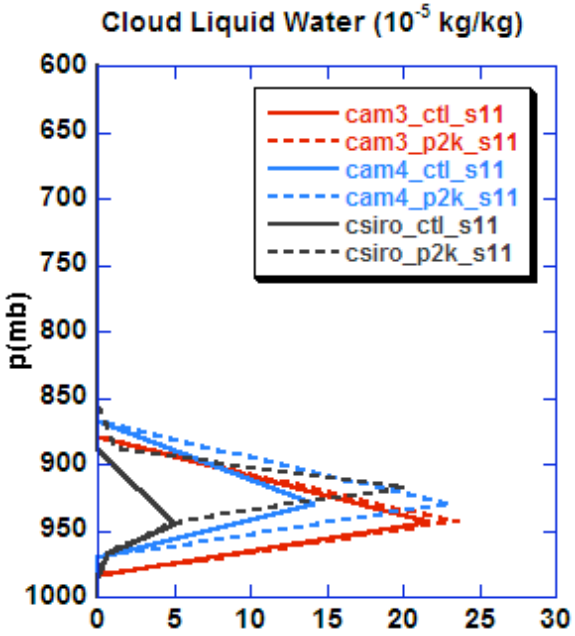
10

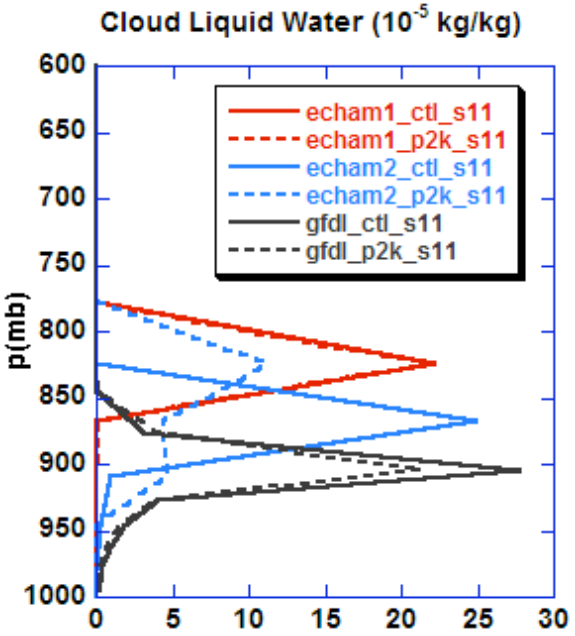
Cloud Liquid Water in Control Simulation

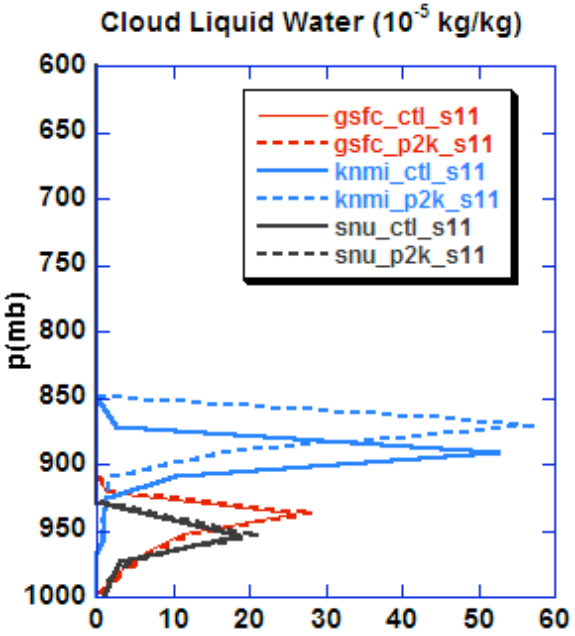


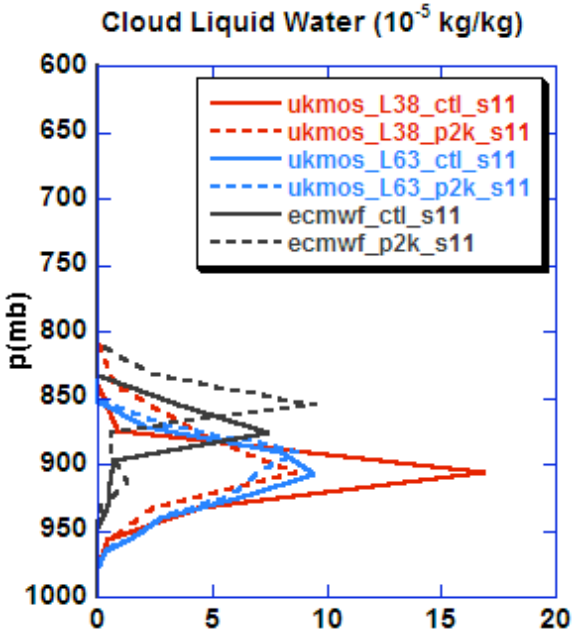

LWP (g/m2)
LWP(g/m2)
200
150
100
50
0
s11
cam3
cam4
ccc
csiro
csiro2
echam
echam2
ecmwf
gfdl
giss
giss2
gsfc
knmi
knmiB
larc
larcB
lmd
sam
samB
snu
ukmo
ukmo38
ukmo63
ukmoB
ukmoC
uwm

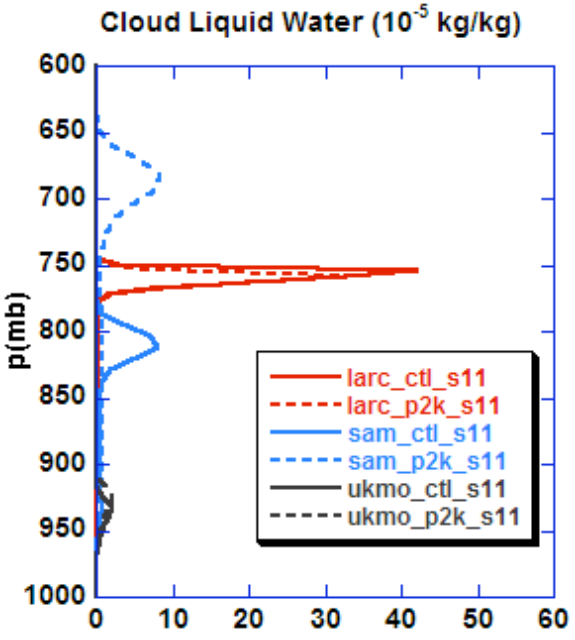

Cloud Liquid Water (10-5 kg/kg)
p(mb)
cam3_ctl_s11
cam4_ctl_s11
csiro_ctl_s11
Cloud Liquid Water (10-5 kg/kg)
p(mb)
echam1_ctl_s11
echam2_ctl_s11
gfdl_ctl_s11
Cloud Liquid Water (10-5 kg/kg)
p(mb)
gsfc_ctl_s11
knmi_ctl_s11
snu_ctl_s11
Cloud Liquid Water (10-5 kg/kg)
p(mb)
ukmos_L38_ctl_s11
ukmos_L63_ctl_s11
ecmwf_ctl_s11
Cloud Liquid Water (10-5 kg/kg)
p(mb)
larc_ctl_s11
sam_ctl_s11
ukmo_ctl_s11

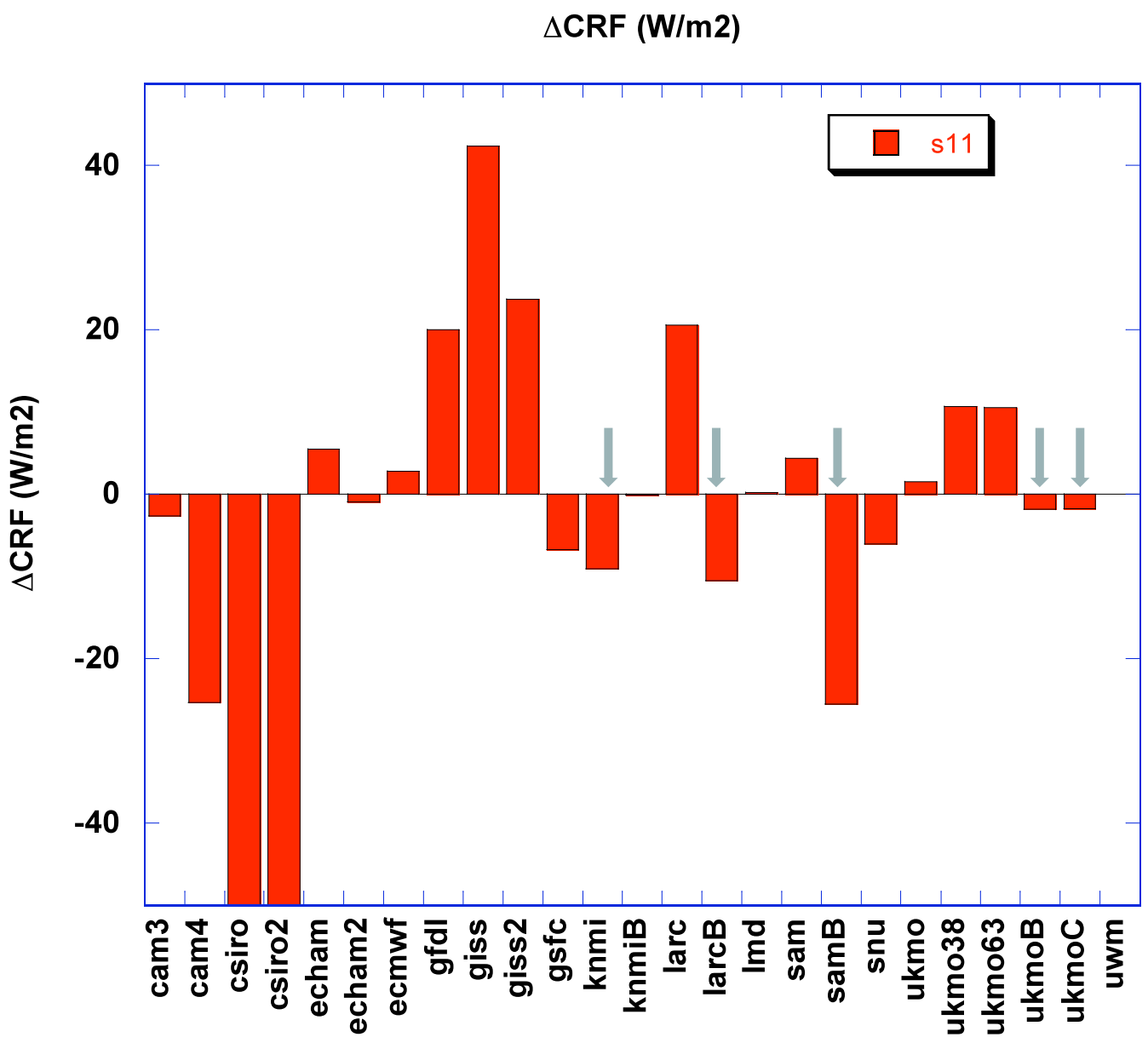

Cloud Liquid Water (10^{-5} kg/kg)
p(mb)
cam3_ctl_s11
cam3_p2k_s11
cam4_ctl_s11
cam4_p2k_s11
csiro_ctl_s11
csiro_p2k_s11


Cloud Liquid Water (10^{-5} kg/kg)
p(mb)
echam1_ctl_s11
echam1_p2k_s11
echam2_ctl_s11
echam2_p2k_s11
gfdl_ctl_s11
gfdl_p2k_s11


Cloud Liquid Water (10^{-5} kg/kg)
p(mb)
gsfc_ctl_s11
gsfc_p2k_s11
knmi_ctl_s11
knmi_p2k_s11
snu_ctl_s11
snu_p2k_s11


Cloud Liquid Water (10^{-5} kg/kg)
p(mb)
ukmos_L38_ctl_s11
ukmos_L38_p2k_s11
ukmos_L63_ctl_s11
ukmos_L63_p2k_s11
ecmwf_ctl_s11
ecmwf_p2k_s11

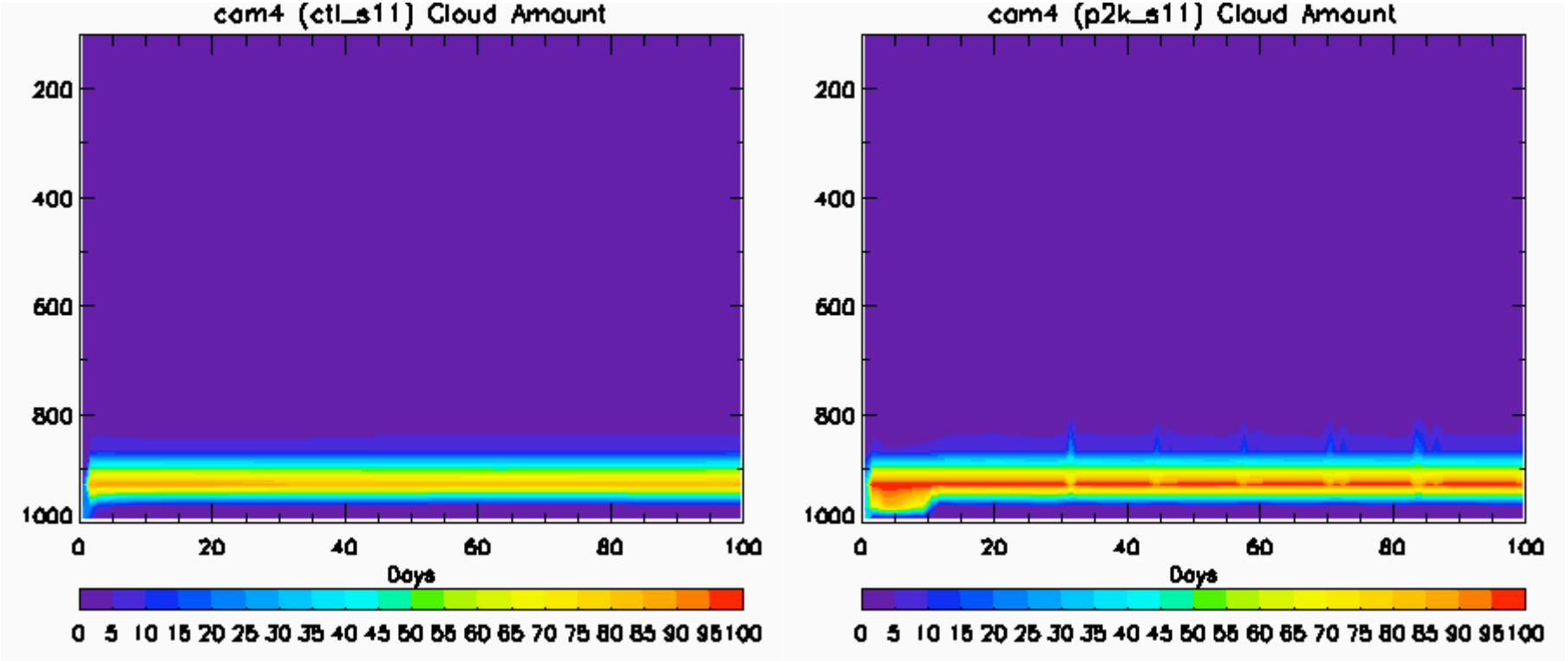

Cloud Liquid Water (10^{-5} kg/kg)
p(mb)
larc_ctl_s11
larc_p2k_s11
sam_ctl_s11
sam_p2k_s11
ukmo_ctl_s11
ukmo_p2k_s11


ΔCRF (W/m2)
s11
ΔCRF (W/m2)
40
20
0
-20
-40
cam3
cam4
csiro
csiro2
echam
echam2
ecmwf
gfdl
giss
giss2
gsfc
knmi
knmiB
larc
larcB
lmd
sam
samB
snu
ukmo
ukmo38
ukmo63
ukmoB
ukmoC
uwm

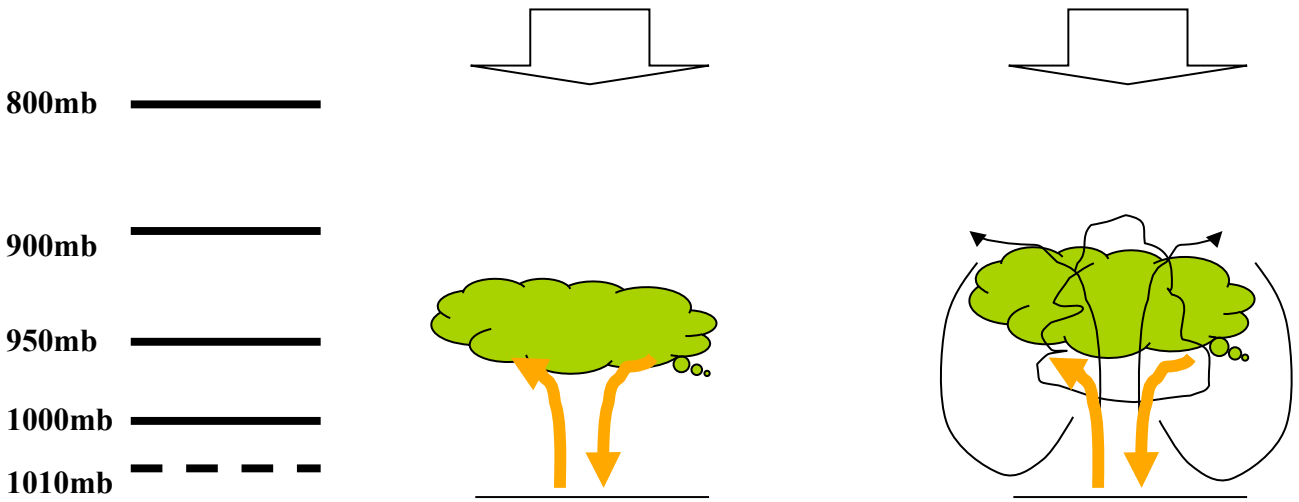
Negative Feedback in CAM4

ctl

p2k

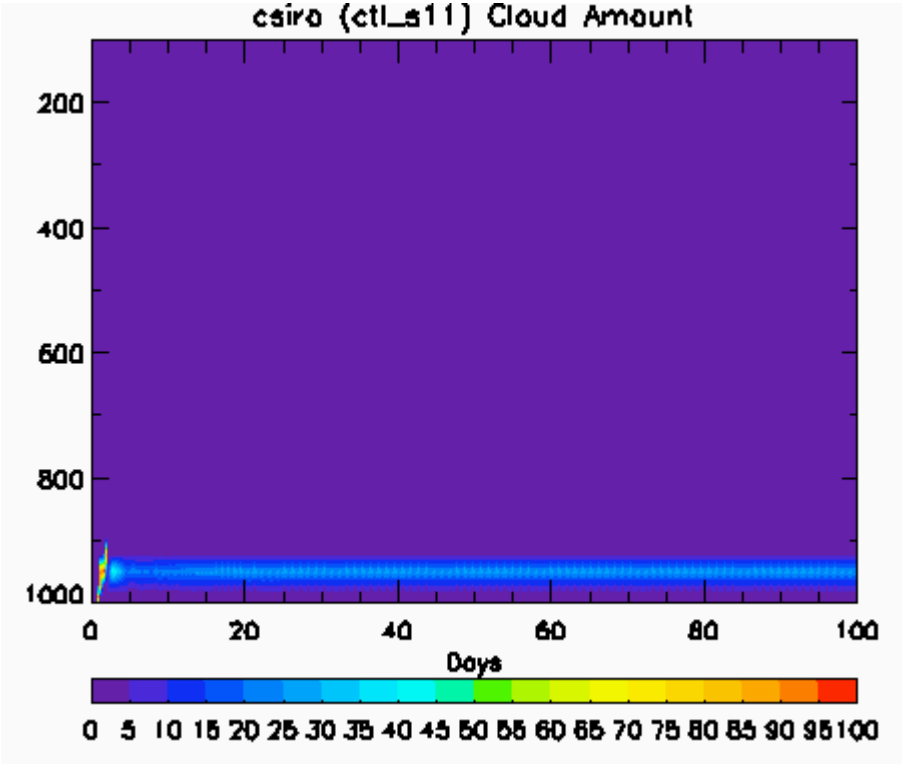


CAM4

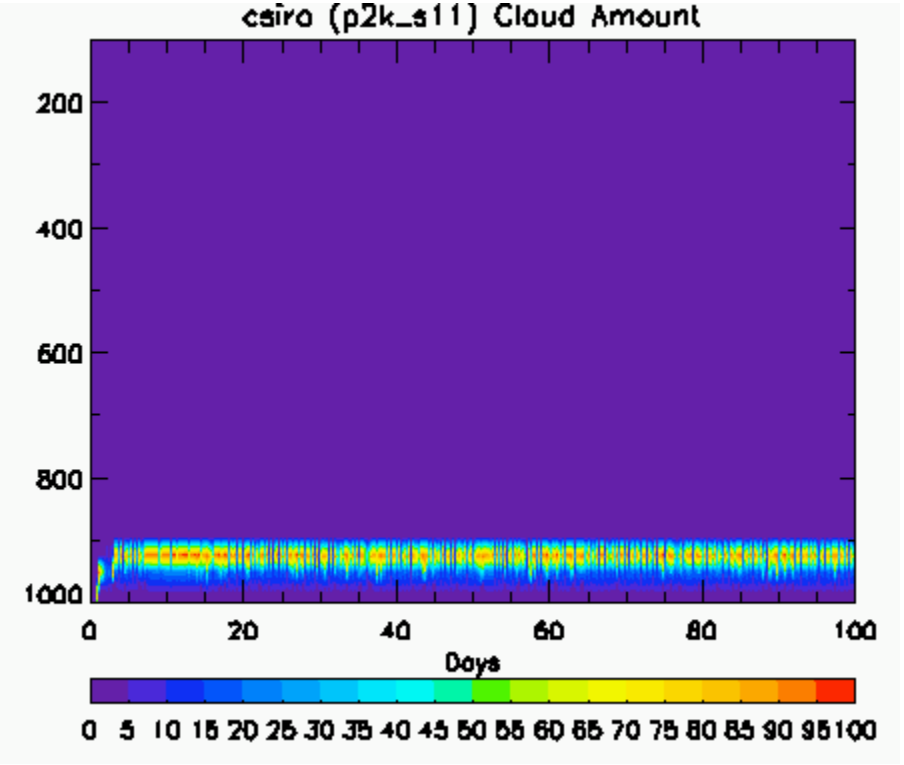


Negative Feedback in CSIRO

ctl

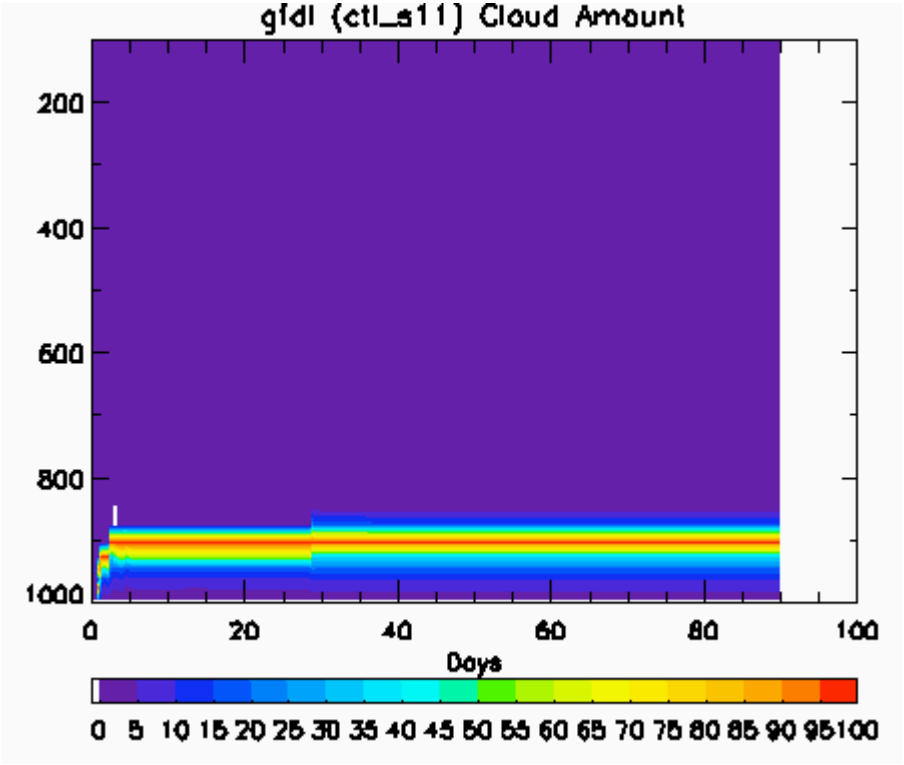


p2k

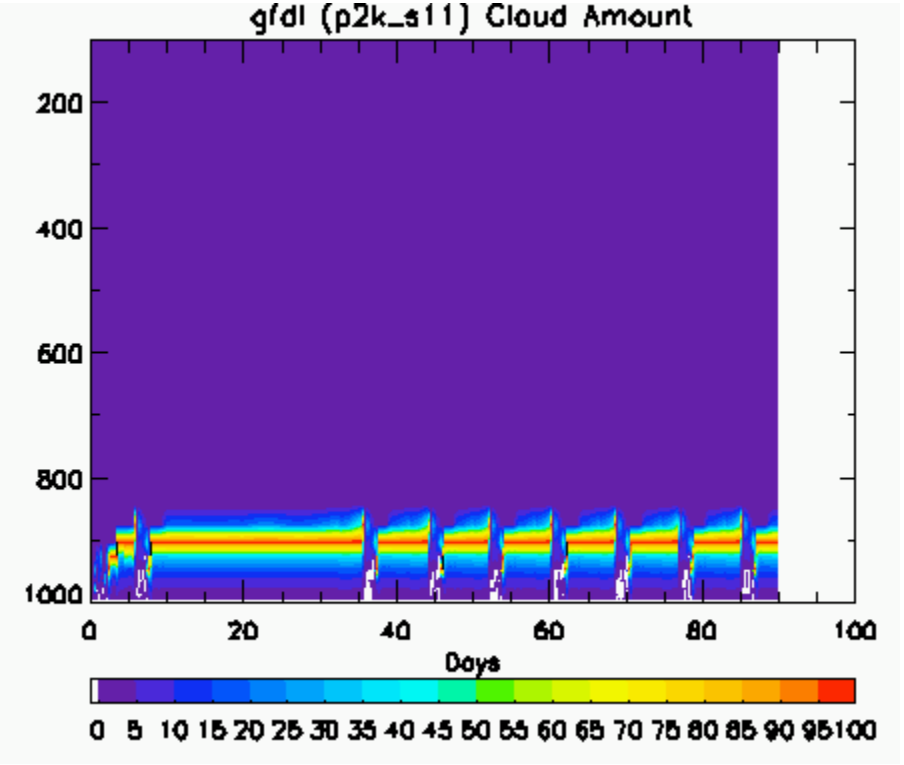


Positive Feedback in GFDL

ctl

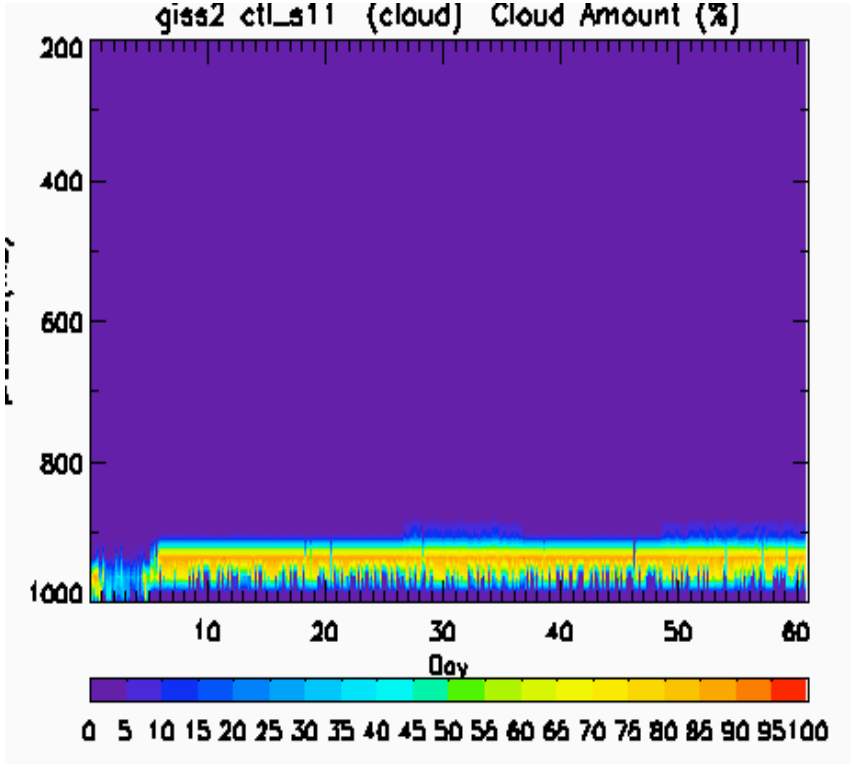


p2k



Positive Feedback in GISS

ctl



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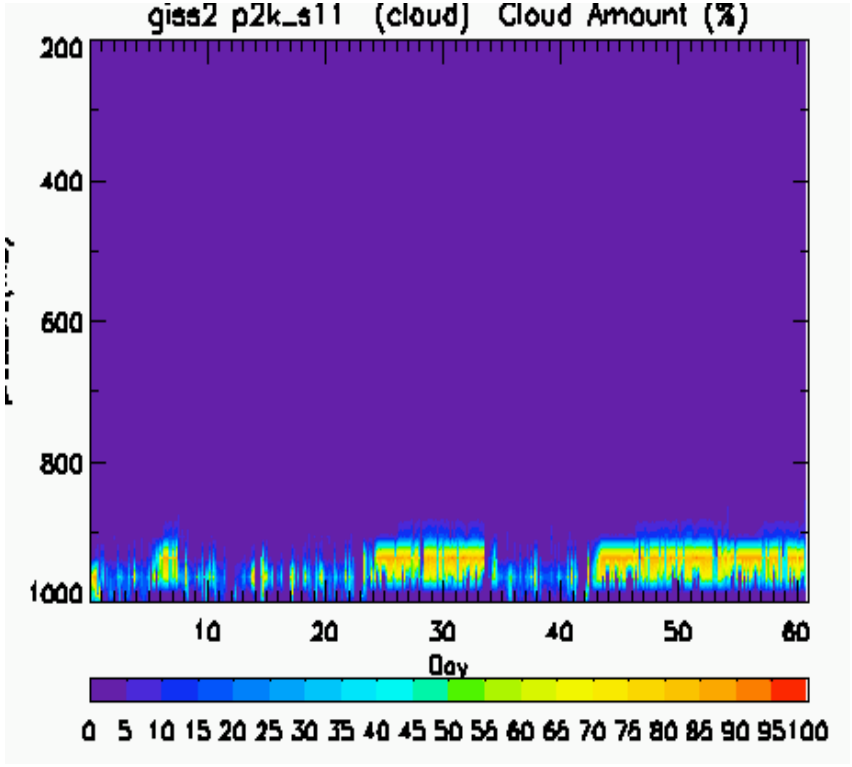
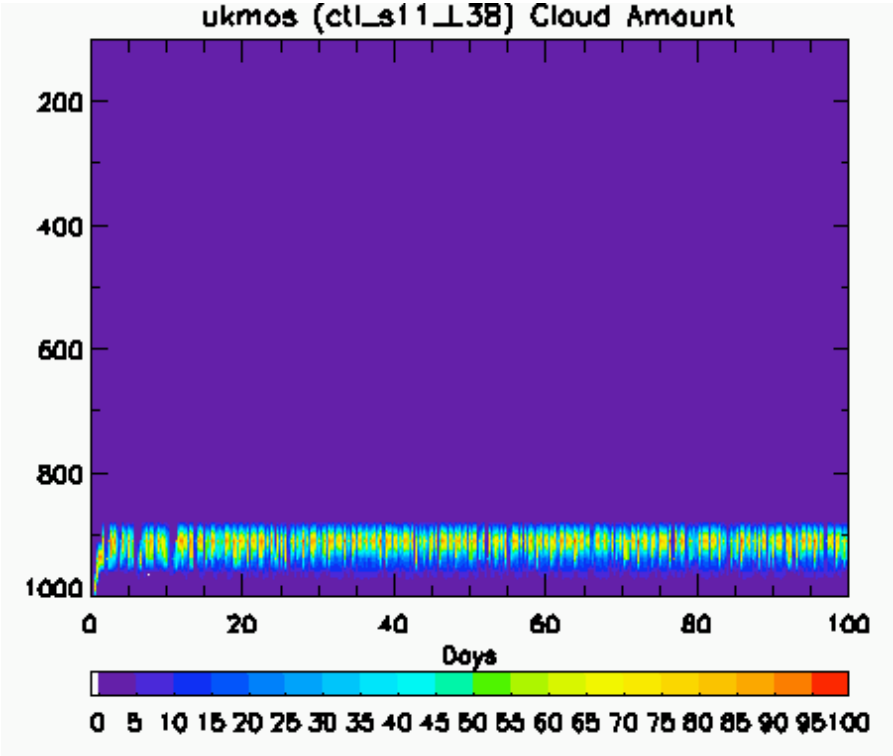


Positive Feedback in UKMO L38

ctl



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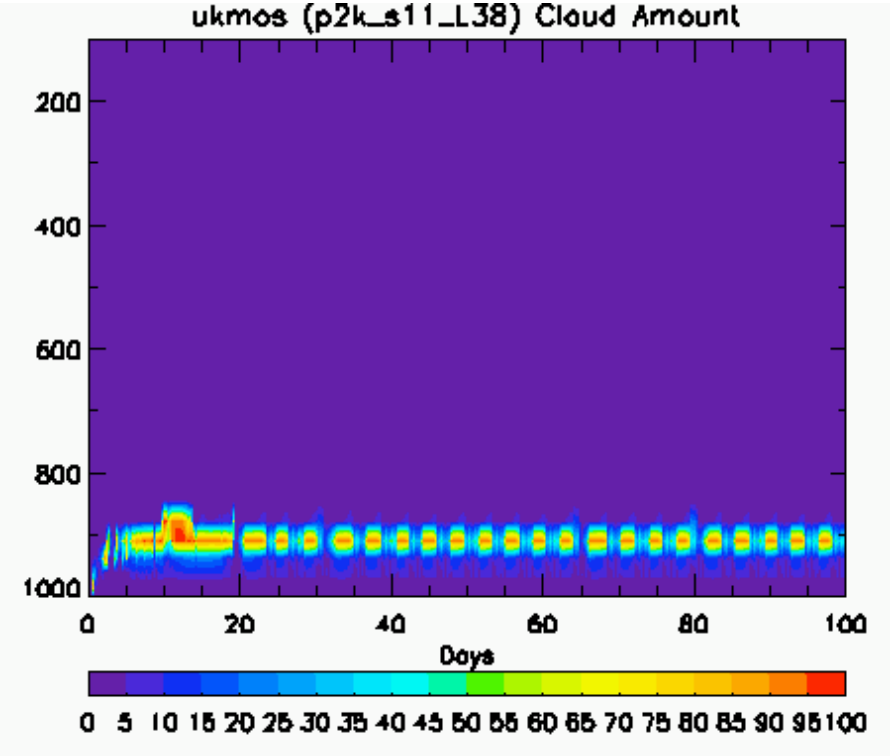
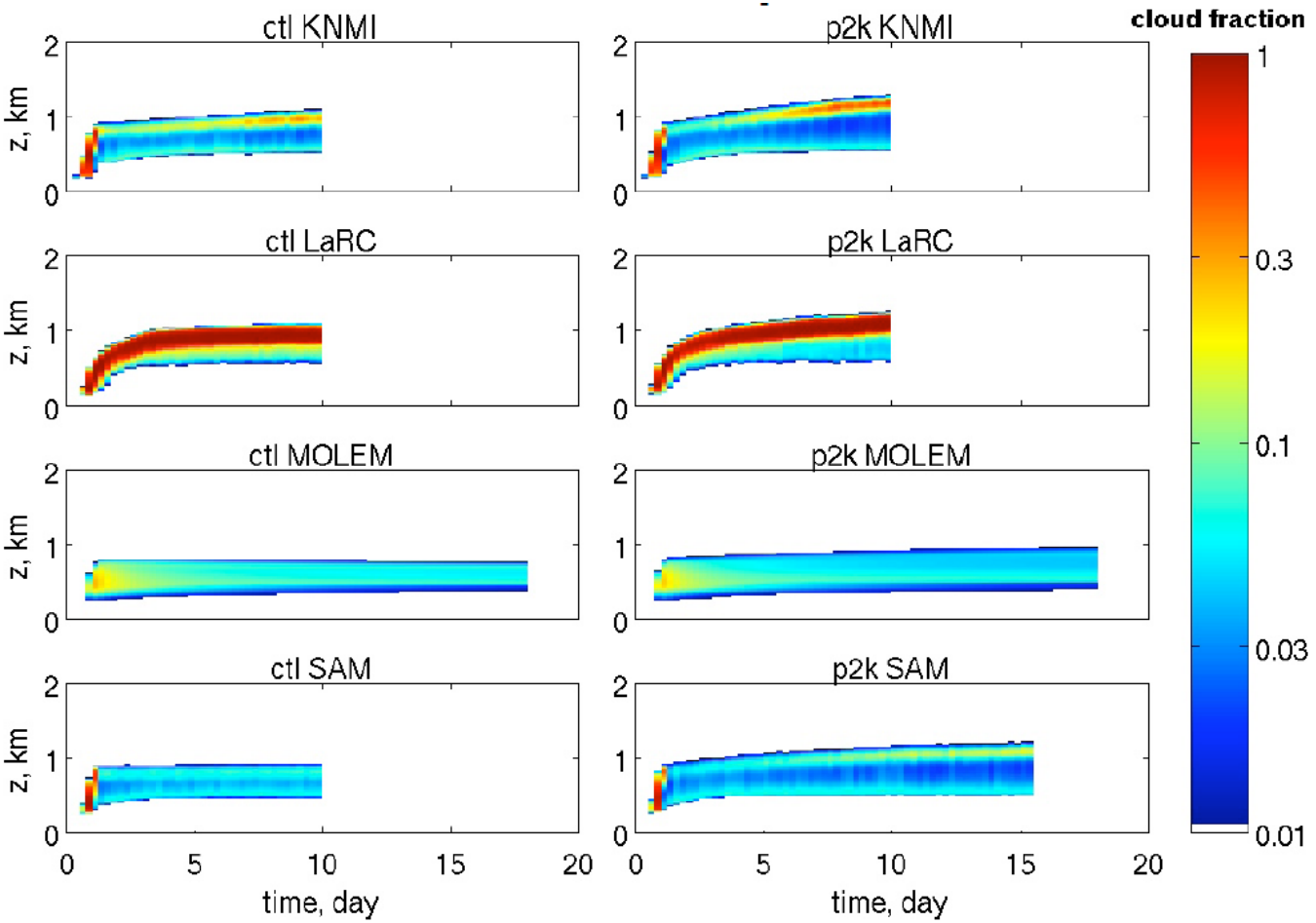


Negative Feedback in the LES



LES has not converged yet

Summary

1. The models simulated the intended types of low clouds and the range of cloud feedbacks

2. The negative feedbacks are due to larger turbulent water transport to the upper boundary layer; the positive feedbacks are due to break-up of clouds

3. Vertical resolution in current models is insufficient for low clouds; they require new ways of parameterizations

4. Interaction of PBL turbulence, convection, stratiform clouds, and radiation needs to be understood

Next Steps

1. LES equilibrium and convergence tests
2. Use seasonal variation as a test
3. Connecting to GCM climate sensitivity
4. Evaluate against observations

CGILS Meeting, March 1-2, 2010

Stony Brook, New York

http://somas.stonybrook.edu/cgils